NASA TECHNICAL TRANSLATION NASA TT F-14,070

PLASMA VOLUME AND CORPUSCLE MASS DETERMINED WITH SERUM ALBUMIN WITH I-131 AND WITH RED CORPUSCLES MARKED WITH Cr-51

G. Rey, A. Macchi and O. Degrossi

Translation of: "Volumen plasmatico y masa globular determinados con seroalbumina con I-131 y con globulos rojos marcados con Cr-51", Argentina Comision Nacional de Energia Atomica, Buenos Aires, Report CNEA-172, 1966, 10 pages.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546 DECEMBER 1971

PLASMA VOLUME AND CORPUSCLE MASS DETERMINED WITH SERUM ALBUMIN WITH I-131 AND WITH RED CORPUSCLES MARKED WITH Cr-51

Guillermo Rey, Alfredo Macchi and Osvaldo Degrossi
National Atomic Energy Commission

ABSTRACT. The corpuscle volume and plasma volume of 16 test subjects were determined by the chromium-51 and the S.A. I-131 methods. Results indicated that the erythrocytic mass is less in women than in men. The S.A. I-131 method was easier to perform, but not as reliable as the Cr-51 method.

General Statements

/3*

The use of radioisotopes in hematological methodology constitutes the most important advance of the last two decades because of its accuracy and ease.

Nevertheless, the evaluation of the Total Blood Volume (TBV), based on the Corpuscle Volume (CV), and on the Plasma Volume (PV), determined simultaneously or successively, with reference to the venous hematocrit (Hct), is subject to error. While an attempt has been made to set up hematocrit correction factors to remedy this difficulty, we are interested in a comparative study of the erythrocytic and plasma masses, separatively, for a direct determination of the circulating Hematic Volume. There are innumerable diagnostic and therapeutic situations in which a knowledge of the volume, and more particularly, the CV or PV independently, is important [2, 5, 6, 7, 3, 13, 22, 28].

---

*Numbers in the margin indicate the pagination in the original foreign text.

Both procedures are based on the principle of isotopic dilution and are directly calculated with the Hct, determining the remaining volume and the total. However, the peripheral Hct does not represent the proportion of cells and plasma in the organism, considered as a whole, and the estimate is only approximate and subject to error [8, 23]. Some researchers believe that if the CV is indirectly calculated, apart from the PV and from the venous Hct [14], we obtain a higher value than that from the direct measurement of the corpuscle mass. They attribute this difference to the fact that the blood concentration in the large vessels is greater than in the peripheral capillaries.

Two correction indices for the common Hct have been proposed. The first would correspond to a plasma trapping mechanism inside the erythrocytic column [18, 20, 25]. The proportion of cells is overestimated, which should be corrected by the factor 0.98. The second corrects the existing disproportion because of the greater dilution of the peripheral capillary stratum and applies the factor 0.92. Although these concepts are accepted by the majority of the authors, there is doubt about the value of the venous (peripheral) and total (body) Hct of the organism.

Various researchers point out different indices [4, 9, 10, 16, 19, 26]. Some believe that they are constant [10], while others suggest that the relation varies individually [11, 14, 15, 16, 27]. What they all agree on is that a real appraisal of the TBV can only be accomplished by independent or joint measurements of both volumes [14]. In this regard, procedures have been described which utilize various tracers [12, 24], applying simultaneous measurement techniques or administering radioactive mixtures. /4

For our part, we do not participate in such simplistic tendencies, and are disposed to a greater clinical application. We feel that the advantages obtained — the utilization of a minimum of equipment, and speed — do not offset the loss in precision and certainty. We estimate that the application of one method, combined with the successive measurement of the CV and of the

PV, supplies a more real evaluation of both fractions, and consequently, of the TBV. For that reason, both procedures are done successively and almost immediately, using Cr-51 to mark the RC [red corpuscles] and completing the study with serum albumin marked with iodine 131 (S.A. I-131).

Although the "RISA" technique is easier to perform, the one that utilizes radio-chromium to determine the CV is considered more exact [22]. Up to the present time, [14, 15, 17, 21] innocuous and stable radioactive chemical substances, constituting the common dosages, are the most widely used. This facilitates the repetition of tests within the permissible radiation limits.

Material and Methods

The tests were performed on 10 healthy, adult volunteers (three women and seven men) and on six patients (four suffering from anemia and two from polycythemia) (Table I). Successively and with a time difference of 30 to 60 minutes, the corpuscle mass was determined by the chromium 51 method, and the PV — with the S.A. I-131 procedure. The Hct was used twice, obtaining an average for each case. Apart from the CV obtained by radio-chromium, and based on the Hct corrected by the aforementioned factors, the TBV is determined, and the PV, by the difference. With the same procedure and apart from the PV obtained with the S.A. I-131, the TBV is obtained for this method, and the CV. In order to compare the values obtained in each individual case, they are taken in reference to the corresponding body weight.

Results: In Table I, the values found from the comparative estimates with both procedures are listed for the three volumes (CV, PV, TBV). The absolute and relative results have been tabulated in ml/kg of weight for ten normal and six pathological subjects (two women and four men).

In Table II, the averages obtained and their deviations in CV, PV and TBV are compared for the two procedures. For the entire population which

TABLE I. CORPUSCLE VOLUME, PLASMA VOLUME AND TOTAL BLOOD VOLUME
COMPARATIVE CONCLUSIONS WITH Cr-51 AND SERUM ALBUMIN I-131

Case	Diagnosis	Sex	Age	Weight (kg)	Height (cm)	(values expressed in cc/kg)					
						Chromium-51			S.A. I-131		
						CV	PV	TBV	CV	PV	TBV
1	Normal	F	33	90	156	19.7	35.8	55.5	20.7	36.3	57.0
2	Normal	F	48	80	162	21.5	38.3	59.8	23.8	37.7	61.5
3	Normal	M	31	59	156	24.3	34.3	58.6	24.1	32.1	56.2
4	Normal	M	33	81	170	28.5	34.6	63.1	29.1	35.1	64.2
5	Normal	M	26	79	160	28.3	39.4	67.7	28.6	36.5	65.1
6	Normal	M	44	72	171	25.9	36.7	62.6	25.1	36.9	62.0
7	Normal	F	28	52	151	23.8	34.9	58.7	24.0	35.1	59.1
8	Normal	M	34	63	160	29.0	46.1	75.1	28.2	46.3	74.5
9	Normal	M	50	70	162	24.3	30.8	55.1	24.4	32.2	56.6
10	Normal	M	56	57	168	28.9	44.3	73.2	28.0	44.9	72.2

(continued on next page)

TABLE I. CORPUSCLE VOLUME, PLASMA VOLUME AND TOTAL BLOOD VOLUME
COMPARATIVE CONCLUSIONS WITH Cr-51 AND SERUM ALBUMIN I-131

Case	Diagnosis	Sex	Age	Weight (kg)	Height (cm)	(values expressed in cc/kg)					
						Chromium-51			S.A. I-131		
						CV	PV	TBV	CV	PV	TBV
11	Anemia	M	14	45	155	21.4	44.5	65.9	20.0	43.5	63.5
12	Anemia	M	25	73	158	18.9	26.7	45.6	18.0	30.0	48.0
13	Anemia	M	37	67	182	20.7	40.0	60.7	19.2	39.3	58.5
14	Anemia	F	35	64	156	16.6	36.9	53.5	16.8	36.7	53.5
15	secondary polycythemia	F	48	48	166	31.8	39.0	70.8	30.5	38.7	69.2
16	true polycythemia	M	60	52	162	59.2	39.9	99.1	62.5	42.5	105.0

makes up the series (No. 16), the means were calculated with their standard deviations and statistical significance [1]. In making an appraisal, there are few manifest differences. The total values given are in agreement with those reported by other authors. The validity of the procedures used confirms the statistical determination, which shows little or no significant difference (at most 0.9).

Table III shows the averages and their deviations for both procedures, related to ml/kg of weight, corresponding to the ten normal subjects. The agreement is also apparent, as was expected. The statistical study shows a greater similarity in CV values, with a slight, insignificant difference in the plasma values.

Table IV gives a comparison of the normal values for men and for women, respectively. The conclusions are analogous to those of the preceding table. No significant difference appears between both procedures, but comparing the normal values of men and women (Table V) statistically for the chromium 51 method, which we select at random, the result would be similar to S.A. I-131. We observe that the corpuscle mass is less in the women, as was expected. The PV values are also somewhat less in the same group, though the difference is not significant. Table VI presents the comparison between normal and anemic subjects for the Cr-51 procedure. The differences of the two groups are significant with respect to TBV and CV, but not the PV. And finally, Table VII offers a comparison of normal values with regard to the polycythemic subjects. Here also the same conclusions are reached as in the preceding table. The differences observed in the pathological group compared to the normal group are not as significant as was hoped, except for the PV values, due to the small number of cases.

Resume and Conclusions

For the present work, a series of 16 cases was selected, divided into two groups: ten normal subjects and six pathological (anemic and polycythemic) subjects.

TABLE II. COMPARISON OF THE VALUES OBTAINED WITH Cr-51 AND SERUM ALBUMIN I-131 FOR THE TOTAL BLOOD VOLUME, THE CORPUSCLE VOLUME, AND THE PLASMA VOLUME (STATISTICAL PROBABILITY "p", IN AGREEMENT WITH THE STUDENT "t" VALUE

	average values		
	Cr-51	S.A. I-131	"p"
TBV	64.0 ± 7.2	63.5 ± 7.9	0.8
CV	26.4 ± 9.3	26.4 ± 10.4	0.9
PV	37.6 ± 4.9	37.1 ± 5.4	0.9

TABLE III. COMPARISON OF THE VALUES FOUND IN NORMAL SUBJECTS WITH Cr-51 AND SERUM ALBUMIN I-131 (AVERAGES, STANDARD DEVIATIONS, AND STATISTICAL PROBABILITY "p")

	average values		"p"
	Cr-51	S.A. I-131	
TBV	69.2 ± 3.7	61.8 ± 4.1	0.6
CV	25.4 ± 3.2	25.6 ± 2.7	0.9
PV	37.5 ± 4.3	36.2 ± 5.5	0.6

TABLE IV. COMPARISON OF THE VALUES OBTAINED IN NORMAL SUBJECTS OF BOTH SEXES
(AVERAGES, STANDARD DEVIATIONS AND STATISTICAL PROBABILITY "p")

		average values		
		Cr-51	S.A. I-131	"p"
Male 7 cases	TBV	65.0 ± 4.8	64.4 ± 4.9	0.8
	CV	27.0 ± 2.0	26.8 ± 2.0	0.9
	PV	38.0 ± 7.7	37.6 ± 7.9	0.9
Female 3 cases	TBV	58.7 ± 3.4	55.8 ± 5.0	0.6
	CV	22.7 ± 3.7	22.8 ± 3.8	0.9
	PV	36.0 ± 1.9	33.0 ± 6.3	0.7

TABLE V. COMPARISON OF THE VALUES OBTAINED WITH Cr-51 FOR MALES AND FEMALES
(AVERAGES, STANDARD DEVIATIONS AND PROBABILITY "p" VALUE)

	Male ml/kg	Female ml/kg	"p"
TBV	65.0 ± 4.8	58.7 ± 3.4	0.1
CV	27.9 ± 2.0	22.7 ± 5.0	0.2
PV	38.0 ± 7.7	36.0 ± 1.9	0.6

TABLE VI. COMPARISON OF THE VALUES OBTAINED WITH Cr-51 FOR THE NORMAL AND ANEMIC SUBJECTS (AVERAGES, STANDARD DEVIATIONS AND STATISTICAL PROBABILITY "p")

	Normal (10 cases) ml/kg	Anemic (4 cases) ml/kg	"p"
TBV	64.0 ± 7.2	56.4 ± 4.6	0.1
CV	26.4 ± 9.5	19.4 ± 2.1	0.3
PV	37.6 ± 4.9	37.0 ± 7.1	0.9
Hct	44.4 ± 2.7	35.7 ± 0.8	0.01

TABLE VII. COMPARISON OF THE VALUES OBTAINED WITH Cr-51 IN NORMAL AND POLYCYTHEMIC SUBJECTS (AVERAGES, STANDARD DEVIATIONS. THE VALUE OF "p" IS SUPPLIED AS BEING ONLY INFORMATIVE, GIVEN THE SMALL NUMBER OF POLYCYTHEMIC SUBJECTS).

	Normal (10 cases) ml/kg	Polycythemic (2 cases) ml/kg	"p"
TBV	64.0 ± 7.2	84.9 ± 7.0	0.01
CV	26.4 ± 9.5	45.5 ± 13.7	0.1
PV	37.6 ± 4.9	39.4 ± 0.4	0.6
Hct	44.4 ± 2.7	57.0 ± 8.0	0.01

6 The arithmetical means and standard deviations are given.

Each of the participants was subjected separately and successively to the direct measurement of his CV with Cr-51 and of his PV with S.A. I-131, almost immediately, in that order, in a combined method. Then, the induced TBV's were calculated, applying the peripheral Hct correction factors to obtain the true total or body Hct. The differences from the statistical point of view are not significant (p greater than 0.5) with regard to total values, when both methods are compared. It verifies the fact that the erythrocytic mass is less in women, compared to men. The PV values are also somewhat less in the same group, but without significant differences. On the other hand, the opposite is true for the TBV's (p less than 0.1). In the same way, the differences between the normal and pathological subjects (whether anemic or polycythemic) are statistically significant for the CV and TBV. For more exact measurements, while the aforementioned Hct correction indices are not modified, it is advantageous to make separate, direct determinations of both volumes. The two procedures prove to be reliable and of great value. While the S.A. I-131 procedure is easier to do, it is not as sure as the Cr-51 method, since the differing purity of the albumin used can vary its accuracy, but in practice it is the one chosen in an emergency.

REFERENCES

1. Bancroft, H. Introducción a la Bioestadística (Introduction to Biostatistics). Eudeba, Buenos Aires, 1960.

2. Beimaltes, W.H., P.C. Johnson and A.J. Solari. Clinical Use of Radioisotope. Philadelphia. W.B. Saunders Co., 1957.

3. Berlin, N.I. Radioisotopes in Medicine U.S.A.E.C. Washington Chapter 30: Blood Volume, Methods and Results. 1955, p. 429.

4. Berson, S.A. Blood Volume in Health and Disease. N.Y. Acad. Med., Vol. 30, 1964, p. 750.

5. Beivin, P., I. Bernard, J. Dormont and H. Pequignot. What is the Place of the Measurement of the Blood Volume in Medical Practice? Presse Medical, Vol. 77, 1962, p. 1453.

6. Burrows, B.A. Tracer Studies in Medical Diagnosis. Med. Clin. North Amer., Philadelphia, W.B. Saunders Co., September 1959.

7. Clinical Use of Radioisotopes. A Manual of Technique. Edited by T. Fields and L. Seed, Chicago, Year Book Publisher, 1957.

8. Creysel, J., H. Creysel,R. Delenye and M. Lecordier. Measurement of Variations in Blood Volume with Radiochromium 51 Labeled Erythrocytes. Lyon Clin., Vol. 57, 1961, p. 744.

9. Chaplin, H. Jr., and P.L. Mollison. Correction for Plasma Trapped in the Red Cell Column of the Hematocrit. Blood, Vol. 7, 1952, p. 1227.

10. Chaplin, H. Jr., P.L. Mollison and H. Vetter. The Body/Venous Hematocrit Ratio. Its Contancy Over a Wide Hematocrit Range. J. Clin. Invest. Vol. XXXII,1953, p. 1309.

11. Fundenberg, H., M. Badini, J. Mahoney and W. Damesheck. The Body Hematocrit Venous Hematocrit Ratio and the Splenic Reservoirs. Blood, Vol. 17, 1961, p. 71.

12. Gray, S.J. and H. Frank. The Simultaneous Determination of Red Cell Mass and Plasma Volume in Man with Radioactive Sodium Chromate and Chromic Chloride. J. Clin. Invest., Vol. 32, 1953, p. 1000.

13. Gregersen, M.I. and R.A. Rawson. Blood Volume. Physiol. Rev., Vol. 39, 1959, p. 307.

14. Gurney, C.W. and R.J. Bolt. The Simultaneous Use of Chromium Labeled Erythrocytes and I-131 Tagged Human Serum Albumin in Blood Volume Determinations. Univers. Michigan Med. Bull., Vol. 22, 1956, p. 319.

15. Hart, D. and J. Metz. The Estimation of Red Cell Volumes with 51 Chromium Labeled Erythrocytes and Plasma Volume with Radio-dinated Human Serum Albumin. J. Clin. Path., Vol. 15, 1962, p. 459.

16. Hope, A. and D. Verel. Further Observations on the Distribution of Red Cell and Plasma in Disease. The Low Body Hematocrit Ratio. Clinical Sci., Vol. 14, 1955, p. 501. /10

17. Klement, A.W. Jr., D.E. Ayes and D.R. McIntyre. Simultaneous Use of I-131 Albumin and Cr-51 Labeled Red Cells in Blood Volume Studies in the Goat. Proc. Soc. Exp. Biol. Med., Vol. 87, 1951, p. 81.

18. Leeson, D. and E.C. Reeve. The Plasma in the Packed Cell Column of the Hematocrit. J. Physiol., Vol. 115, 1951, p. 129.

19. Linn, P.E., B. Rothfeld and R.T. Shkelfort. An Evaluating of Radioactive Chromatic Blood Volume Studies. Guthrie Bulletin, Vol. 32, 1962, p. 41.

20. Owen, C.A. Jr., and M.N. Owen. Intercellular Plasma of Centrifuged Human Erythrocytes as Measured by Means of Iodine 131 Albumin. J. Applic. Physiol., Vol. 5, 1953, p. 323.

21. Pieroni, R.R., V. Maspes, J. Rieffer, R. Carelli, M.A. Jamba, J.C. Barberio and A.B. De Ouhoa Cintra. Uso de radioisotopos en propedeutica hematologica (Use of Radioisotopes in Hematological Propedeutics). Use of Radioisotopes in Animal Biology and the Sciences. Vol. 1, Acad. Press., London-New York 1962. Public. for the A.E.I. Agency, p. 371.

22. Reeves, J.D. Clinical Applications of Radioactive Isotopes. New England J. Med., Vol. 257, 1957, p. 454.

23. Remington, J.W. and C.H. Baker. Evolution of Blood Volume Measurement Techniques. Circulation Res., Vol. 9, 1961, p. 60.

24. Shires, T., M. Williams and F. Brown. Simultaneous Measurement of Plasma Volume, Extracellular Fluid Volume and Red Cell Blood Mass in Man Utilizing I-131, S 36 04 and Cr-51. J. Lab. and Clin. Med., Vol. 55, 1960, p. 776.

25. Vazquez, O.N., K. Newerly, R.S. Yalow and S.A. Berson. Determination of Trapped Plasma in the Centrifuged Erythrocyte Volume of Normal Human Blood with Radioiodinated (I-131) Human Serum Albumin and Radiosodium (Na 24). J. Lab. Clin. Med., Vol. 39, 1952, p. 595.

26. Veall, N. and H. Vetter. Radioisotope Techniques in Clinical Research and Diagnosis. Butterwoods Ed. London 1958, p. 223.

27. Verel, D. Observation on the Distribution of Plasma and Red Cells in Disease. Clinical Sci., Vol. 13, 1954, p. 51.

28. Yalow, R.S. and S.A. Verson. Some Applications of Isotope Dilution Techniques. Amer. J. Roentgenal., Vol. 75, 1956, p. 1059.

Translated for National Aeronautics and Space Administration under Contract No. NASw 2035, by SCITRAN, P.O. Box 5456, Santa Barbara, California, 93108.